

# **REPS GLOSSARY of TERMS (©2002)**

<b>Word</b>	<b>Page</b>	<b>Word</b>	<b>Page</b>
<b>A</b>		<b>D</b>	
Accuracy	4	Data Acquisition System (DAS)	9
Active Voltage Suppression	4	deciBel (dB)	9
Alternating Current (AC)	4	Degree	9
Aluminum Conductor, Steel Reinforced Cable (ACSR)	4	Delta ( $\Delta$ ) System	9
Ammeter	4	Digital Multimeter (DMM)	9
Ampere	4	Digital Signal	10
Amplitude	5	Direct Current (DC)	10
Amplitude Modulation (AM)	5	Distribution System	10
Analog Signal	5	Distribution Voltage Level	10
Analog-to-Digital Converter (ADC)	5	<b>E</b>	
Antenna	5	Earth	10
Attenuation	5	Earth Current	10
Auto-ranging	5	Electric field	11
<b>B</b>		Electric Shock	11
Balanced Phases	6	Electricity	11
Band Limit	6	Electrocution	11
Bandwidth	6	Electro-magnetic Field (EMF)	11
Bare Concentric Neutral	6	Electro-magnetic Induction (EMI)	12
Black-out	6	End-of-line Customer (EOL Customer)	12
Branch Circuit	6	Equipotential Plane (EPP)	12
Brown-out	6	<b>F</b>	
<b>C</b>		Filter Circuit	12
Capacitor (C)	7	Five-wire System	12
Capacitive coupling	7	Floating System	12
Central Yard Pole (CYP)	7	Four Main SV Electrical Parameters	12
Circuit Breaker	7	Four-wire System	12
Conduction	7	Frequency	12
Conductor	7	Frequency Modulation (FM)	13
Cooperative Utility (Coop)	7	Fully Jacketed Cable	13
Copperweld Cable (CW)	8	Fundamental Frequency	13
Counterpoise System	8	Fuse	13
Cow Contact Area	8	<b>G</b>	
Cow Contact Current (Icc)	8	Galvanic Effect	13
Cow Contact Voltage (Vcc)	8	Gauss	13
Current (I)	8	Gaussmeter	13
Current Balancing Transformer (CBT)	8	Generation System	13
Current Limiting Device	8	Giga- (G)	14
Current Return Ratio (CRR)	8	Ground	14
Cycle	9	Ground Current	14
		Ground Loop	14
		Ground Referenced System	14
		Grounded Conductor	14

Grounding Electrode Conductor	14
Grounding Electrode	14

## **H**

Harmonic	14
Hertz (Hz)	15
Horsepower (hp)	15

## **I**

Impedance (Z)	15
Induction	15
Inductor (L)	15
Input Impedance	15
Insulator	15
Interface	16
Interference	16
Investor-owned Utility (IOU)	16
IR drop	16
Isolation Transformer	16

## **J**

Johnson Noise	16
---------------	----

## **K**

K-factor	16
kilo- (k)	16
kiloVoltAmpere (kVA)	16
Kirchhoff's Current Law (KCL)	17
Kirchhoff's Voltage Law (KVL)	17

## **L**

Least-significant Bit (LSB)	17
Level-of-concern (LOC)	17
Load Box Test (LB test)	17
Load Device	18

## **M**

Magnetic Field	18
Main Disconnecting Means	18
Mega- (M)	18
Micro- ( $\square$ )	18
Milli- (m)	18
Multi-grounded System	18
Municipal Utility (muni)	18

## **N**

Nano- (n)	18
National Electric Code (NEC)	18
National Electric Safety Code (NESC)	19
Neutral Conductor	19
Neutral Current	19
Neutral Isolator Device	19
Neutral to Earth Voltage (NEV)	19
Noise	19
Non-linear Load	19

## **O**

Off-farm	19
Ohm's Law	19
Ohmmeter	20
On-farm	20
Open Wye, Open Delta System	20
Oscilloscope	20
Other Electrical Phenomena(OEP)	20
Over-current Device	20

## **P**

Parallel Circuit	20
Parallel Resistors	20
Peak (pk)	21
Peak-to-Peak (pp)	21
Phase Conductor	21
Phase I Protocol	21
Phase II Protocol	21
Potential Difference	21
Power Factor (PF)	21
Power Quality (PQ)	21
Power Transfer Switch	21
Precision	21
Primary Electrical System	22
Primary Neutral to Reference Voltage (Vpnref)	22
Primary Profile Test	22
Primary Underground Conductor Protocol	22

## **Q**

Quarter-wave Antenna	22
----------------------	----

## **R**

Radiation	22
Radio-frequency (RF)	22
Reference Rod	23
Resistance (R)	23
Resistivity	23
Root Mean Square (rms)	23

## **S**

Saturable Reactor	23
Scalar Mathematics	23
Secondary Electrical System	24
Secondary Neutral to Reference Voltage (Vsnref)	24
Secondary Neutral Voltage Drop Test (SNVD test)	24
Series Circuit	24
Series Resistors	24
Shunt Resistance	24
Signal	24

Signal-to-noise Ratio (SNR)	24
Signature Test	24
Significant Digit	25
Sinusoidal Wave	25
Single Phase System	25
Source Resistance	25
Static Discharge	25
Static Wire	25
Steady-state	25
Step Potential	26
Stray Voltage (SV)	26
Substation	26
Sub-Transmission Voltage Level	26
Superposition Theorem	26

## **T**

Tap Pole	26
Three Phase System	26
Three-wire System	26
Tolerance	27
Total Harmonic Distortion (THD)	27
Transformer (xfmr)	27
Transient	27
Transmission System	27
Transmission voltage Level	28

## **V**

Variable Threshold Neutral	
Isolator Device	28
Vector Mathematics	28
Voltage (V)	28
Voltage Drop	28
Voltmeter	28

## **W**

Watt (W)	29
Watt-Hour meter	29
Wattmeter	29
Waveform	29
Wavelength	29
Wye (Y) Configuration	29

**Accuracy** – A parameter describing how closely a measured value is to an ideal or designed value. When a measurement is made, the value measured is approximated as it is presented to the viewer by the measuring device. No device can measure with infinite accuracy. Even the mere presence of a measuring device connected to a circuit modifies that circuit ever so slightly so that the value of the parameter that is to be measured is changed. The difference between the true value and the presented value is a measure of a device's design and performance accuracy. The closer the presented value is to the real value, the more accuracy the measuring device has. The specification of accuracy is often given as a percentage range on each side of the ideal accuracy of 100%, i.e.  $\pm 2\%$  accuracy means the displayed value will be anywhere within a range between 98% and 102% of the true value.

**Active Voltage Suppression (AVS)** – An electronic device used to create a counter-acting electrical signal that would ideally cancel secondary neutral-to-earth voltages and therefore stray voltages. This works on the principal of vector arithmetic (qv) where two signals of equal magnitude but opposite phase add to zero. The opposite phase signal created by the AVS system is connected to a massive grounding electrode system to function properly. AVS systems are not used much presently in Wisconsin, as they are an expensive, high maintenance system and can create significant ground currents in their function of reducing stray voltage on-farm.

**Alternating Current (AC)** – Two types of electrical energy are used by the modern world, alternating current (AC) and direct current (DC) (qv). AC is characterized by an ever-varying amplitude (qv) of voltage or current at a frequency (qv) that is not zero. The waveform's amplitude is usually centered equally above and below a level of zero Volts. When this is not true, it is considered to have a 'DC offset'. One complete cycle of the waveform (qv) defines the basic or fundamental frequency of the AC signal. For commercial electrical power systems this waveform, usually considered sinusoidal (qv) in shape, continuously and endlessly repeats in a steady-state (qv) fashion. Real world AC power sine waves are never absolutely perfect in their wave shape.

**Aluminum Conductor, Steel Reinforced Cable (ACSR)** – A modern type of conductor presently being used to conduct electricity on many primary distribution and transmission systems. It consists of a number of strands of solid aluminum wire wrapped around a central steel cable for strength. The ACSR conductor may have an overall plastic insulating jacket or may be bare. Sizes may vary from as small as #6 or #4 to very large wires measured in MCM (thousands of circular mils). The standard most used in rural areas is 1/0 ACSR wire which is about  $1/4^{\text{th}}$  as resistive as the older copperweld (qv) conductors.

**Ammeter** – A meter used to measure a magnitude of electrical current greater than 1 microAmpere. The measured current may be either AC or DC depending on the design of the meter. There are two basic types. A shunt ammeter is used within a circuit to measure a voltage drop that is proportional to the circuit current across a specific (known) low-resistance shunt element (this is due to Ohm's Law). The circuit must be broken at some point to insert this type of meter. There are DC and AC shunt ammeters. A clamp-on ammeter has a set of movable jaws, which open and close enabling the meter to clamp around the conductor whose current is to be measured without the need of opening the circuit. This type of meter typically works for measuring AC currents, but will measure DC currents with a special adaptor. When the jaws are closed, the meter acts as a small transformer that samples the current without significantly disturbing the circuit. The closed jaws may also pick up induced extraneous magnetic field currents as a noise signal.

**Ampere** – The unit of measure of current. Current (qv) is the flow of physical electrons in a conductive medium. One ampere of current is equivalent to just over six billion, billion electrons past a designated point per second. This makes the basic unit of current a fairly large one, so the usual measure of current is in milliAmperes ( $1/1,000^{\text{th}}$  of an Ampere) or microAmperes ( $1/1,000,000^{\text{th}}$  of an Ampere). Physics dictates that current will not flow without an energy source (voltage source) to push it and will not flow in an incomplete circuit (it must have some conductive path to follow from the source to a load and back to the source again).

**Amplitude** – The (y-axis) value of an AC waveform at any point in time. This may be measured from a zero value to the maximum value as a ‘peak’ (qv) reading or may be measured from the most positive to the most negative value during one cycle as a ‘peak-to-peak’ (qv) reading. Either of these may be mathematically converted to a root mean square (qv) or rms reading knowing the wave shape. In an x-y graphical representation of a waveform, as presented on an oscilloscope (qv) for instance, the amplitude is displayed on the y-axis.

**Amplitude Modulation (AM)** – A type of modulation in which a carrier frequency (a single frequency AC wave that is generally higher than 100 kHz) changes its amplitude in response and in proportion to an audio modulating signal. If no modulating signal is present, only a uniform amplitude, carrier frequency wave is broadcast. The standard AM radio band (containing 118 different channel assignments) assigns carrier frequencies every 10 kHz from 530 kHz to 1700 kHz. The broadcast power allowed by the FCC may vary from 100 watts to 50 kW during the day and as low as less than a watt at night. There are 4,685 commercial AM radio stations in the US. Other communications bands in the US and around the globe also use AM-type modulation up to a carrier frequency of about 30 MHz. AM radio signals can be a form of noise to measurement processes that have ungrounded conductors that act as antennas.

**Analog Signal** - A signal that is always continuous in nature. That is, for any two selected consecutive points in time of the signal there exists a value for that signal between those two points, no matter how closely together the two time points may be defined.

**Analog-to-Digital Converter (ADC)** – A device that converts a real-world, continuous analog signal (qv) to a digital representation of that signal. The advantage of doing so is that digital signals (qv) are easier to process and are more noise (qv) and interference resistant. The disadvantage is that the reconstruction of the original analog signal (digital-to-analog conversion, DAC) can never be done exactly. Some information (i.e. the accuracy of the original signal) is always lost in both conversion processes. Even the digital value is never a 100% accurate representation of the true analog value. The ADC has an expressly designed number of digital bits specified whose various combinations represent the range of analog values the ADC is meant to convert. The ADC unit samples the analog signal on command of a controlling processor at precise and discrete times known as the sample interval. The device does not sample or convert data in between these discrete times. The highest frequency analog signal an ADC can successfully convert is ideally no more than half the sample frequency rate and in practice is usually one-tenth that rate. The higher the sample rate is and the more bits in the converted digital number, the more expensive and more precise the ADC is.

**Antenna** – A conductive device usually intended to receive or transmit radio frequency signals via an electro-magnetic radiation (qv) process. However, any metallic structure that is not grounded at every point can act as an antenna for the reception of incident electro-magnetically radiated signals. The process of transmission or reception of radio waves is most efficient for a quarter-wave antenna (qv). It is important to not confuse received noise from radio and other sources as signals. Long ungrounded distribution power lines act as antennas to many frequencies of EMF radiation.

**Attenuation** – The word used to describe signal amplitude decrease, as opposed to ‘amplification’ which makes signal amplitudes increase. When voltage and current signals pass through passive circuit component networks such as resistors, they are attenuated to some degree. The amount of attenuation may be expressed as a ratio or in deciBels (qv). Radiated signals attenuate more with increased distance from their source for two reasons: the dissipative effect of the ever-widening area they are broadcast through and the dissipative effect of the transmission media (the air and the earth).

**Auto-ranging** – A function built into more sophisticated digital multimeters (DMM’s) (qv) that enables them to automatically display the value of the parameter being measured with the most digits allowable by the meter. Usually, the decimal point and units of measure are manipulated by an internal processor to

accomplish this task. For example, if one is to measure a voltage of exactly 26.00000 millivolts with a meter having a 4-digit display, it could show this as 0.026 V. or 26.00 millivolts. The latter display has more significant digits (qv) (four versus two for the former), so is displayed as more precise. The stated accuracy of the meter must be known in order to interpret whether all the digits presented represent accurate information. For instance, a  $\pm 1\%$  meter on the '100' (99.99) millivolt scale would have the value shown actually be between 25.74 mV and 26.26 mV.

**Balanced Phases** – A condition on either a primary or a secondary AC electrical systems where all hot phases carry the same or nearly the same current. In this condition, there is little or no neutral current. On a three-phase transmission system, the currents in all three phases are nearly balanced because of the inherent nature of the system design. Changing customer load requirements constantly affect the distribution system balance.

**Band Limit** – The upper or lower frequency limit of the band of frequencies specified or of interest. For example, 530 kHz and 1700 kHz are the band limits for the commercial AM radio band and about 45 Hz and 20 kHz are the measurement band limits for a Fluke Model 87 III DMM in the AC voltage or current setting. There are varying accuracy specifications for different portions of this frequency band and the accuracy of the instrument is not specified for measurements that include frequencies outside of these band limits. There is also a limitation of the allowable amplitude of the signal (5 to 100%) within this frequency band for this style of DMM to remain in a specified accuracy range.

**Bandwidth** – A parameter describing the useful range of frequencies an instrument can reproduce or measure without significant degradation or attenuation of the signal. I.e. the accuracy will be guaranteed by the manufacturer for all frequencies within the specified bandwidth. For example, a Fluke Model 87 III DMM will measure within its stated accuracy those voltages between 45 Hz and 20 kHz frequency. For measurements of electrical signals above and below these frequencies, the accuracy of the measurement will be profoundly affected. Even within this bandwidth, there are portions (50 to 60 Hz, e.g.) where the accuracy is greatest ( $\pm 0.7\%$   $\pm 4$  counts) compared to other frequencies within the stated bandwidth.

**Bare Concentric Neutral** – An underground cable with the phase conductor as a central core conductor surrounded by an insulating layer and a network of bare wires forming the neutral. There is no overall insulating jacket. Although the bare wires are exposed to the soil in which the cable is buried, the deterioration of the conductors is normally fairly slow giving a designed practical life for this type of cable of a few decades, unless subjected to very corrosive soil conditions.

**Black-out** – A condition where the voltage of a power supply system drops to a level so low that no useful energy is available for proper load support or function. This is generally considered to be by 5% of normal voltage level. This is one of many conditions affecting power quality. Compare to brown-out (qv).

**Branch Circuit** – A power circuit that branches out from the main disconnect panel to serve selected loads. In farm wiring, many branch services (both 240 v., 240/120 v. and 120 v.) are needed to power all the load devices installed. Each 240 v. branch service should consist of 3 wires (2 phase wires and a grounding wire). Each 240/120 v. branch service should consist of 4 wires (2 phase wires, a neutral wire and a grounding wire) (also used for branches to a sub-panel). Each 120 v. branch circuit should consist of 3 wires (a phase wire, a neutral wire and a grounding wire). Each branch service can be considered an on-farm source of stray voltage.

**Brown-out** – Also known as under-voltage, a condition where there is less voltage than nominal, usually beginning at 70-90% of the nominal voltage level, causing loads to malfunction and demand more current for the same power output. Customer power is usually allowed to vary  $\pm 5\%$  from nominal by Public Service Commission of Wisconsin (PSCW) rules. This is one of many conditions affecting power quality. This

condition may occur when large motors are started on-farm. This condition may also exist from on-farm wiring that has too small a conductor size and is too long a distance for large loads.

**Capacitor** – An electric circuit device consisting basically of two parallel conductive plates separated by a thin insulating (non-conducting) layer. As such, a capacitor will not pass a DC current, but will pass an AC current. Capacitors have many functions in electric circuits, some of which are as DC blocks, as filters, as timing elements, as voltage support devices, etc. Capacitors are rated for their capacitance, measured in the unit of Farads or fractions thereof, the maximum voltage it will withstand and if it is designed for AC or DC service. When capacitors may be used to filter AC signals, they are connected between an energized line with an AC signal and ground. They will therefore shunt high frequencies directly to ground and allow low frequencies to continue past that point on the energized line. Commercial capacitors can be destroyed, sometimes catastrophically, by excessive over-voltage, or wrong service application.

**Capacitive coupling** – A method of coupling energy from one circuit to another, independent circuit without a conductive connection between them. This is accomplished by a ‘virtual capacitor’ that exists between two conductors separated by air or insulation. An AC current will travel through that capacitance. Usually the value of this capacitance is very, very small which severely attenuates the coupled current.

**Central Yard Pole (CYP)** – On a typical farm, a central yard pole is usually the point where a transfer switch (qv) is mounted that receives power from either the main transformer or an on-farm backup generator and where all electrical service drops branch out to the many buildings of the farm that require electrical service.

**Circuit Breaker** – An electric circuit element that is designed to act as a switch that opens when the current flowing through the device exceeds a specific rated amount. The amount of time it takes for the switch to open is inversely proportional to the amount of over-current. I.e. the more over-current existing, the faster the switch opens. At all levels of current below the rating of the device, the switch stays closed. This device can also act as a manual switch to intentionally turn on and off the branch circuit it is wired to.

**Conduction** – One of three physical methods for the transfer of energy by electricity. In this method, a layer of electrons in a conductive medium passes electrical energy along the length of the conductor at the speed of light through a combination of electron travel and photon interaction. Electrons have mass, so they would take infinite energy to travel at the speed of light. They interchange photons (massless particles that do travel at the speed of light) of energy as they travel and that results in the total electrical energy traveling at the speed of light. All conductive elements making up a continuous circuit will have portions of the same electrical energy pass through them. Conductors that are insulated from one another and are not part of the same circuit may unintentionally share a portion of the same AC signals due to inductive or capacitive coupling (qqv). The other methods for the transfer of energy by electricity are radiation and induction (qqv).

**Conductor** – A class of substances that allows electrical energy to flow easily through them. The opposite is an insulator (qv). Conductors include most metals, carbonaceous materials and certain other materials possessing low resistivity (qv). Pure water is generally not considered a good conductor, but water with various ions (dirty or polluted water, e.g.) in it is a reasonable conductor. Conductors range in their conductivity from excellent to poor. The general upper limit of resistance for conductors is about 50 MegOhm.

**Cooperative Utility (Coop)** – An electrical utility formed under the laws of Wisconsin allowing such entities that are member owned. These utilities are not under the direct jurisdiction of the Public Service Commission of Wisconsin. They do adhere to the NEC and NESC (qqv) as they are usually subject to USDA guidelines.

**Copperweld Cable (CW)** – A type of conductor used in distribution systems (qv) made necessary during WW II because of the shortage of copper. A type of conductor made up of a mix of copper clad steel wire and solid copper conductors. It is somewhat brittle over many years of service and fairly resistive per mile of conductor. This type of conductor has been generally superseded by the use of all aluminum or ACSR (qv) conductors.

**Counterpoise System** – A buried conductor system used to aid in establishing a lower resistance ground path for an electrical system. In soil conditions where individual ground rods in parallel do not lower neutral-to-earth voltage sufficiently, a counterpoise, usually of #4 bare copper wire, is buried creating a low resistance ground to earth connection. The system is connected to the existing ground rod system in the area.

**Cow Contact Area** – a cow contact is established by specific PSCW protocol to measure the voltage a cow may be subject to in its normal environment. The usual method of establishing a cow contact is to solidly connect one measurement lead to a metallic water line or stanchion rail and the other measurement lead to the concrete floor not more than five or six feet from the first lead. A method of weighting down the floor contact is used along with a brine-soaked towel to minimize contact resistance. A properly established cow contact will only meet this definition if a mature cow can simultaneously contact both of the selected measurement points. A resistor must be used between the leads for the voltage measurement to represent a cow in the measurement circuit. The value most often used (required by the PSCW) is 500 Ohms.

**Cow Contact Current (Icc)** – The AC current a cow is subject to in its normal environment can be very difficult to measure directly, so a cow contact voltage (qv) measurement is taken across a nominal 500-ohm resistor, which simulates the average resistance (muzzle to rear hooves) of a mature cow. From Ohm's Law, a voltage across this resistance is directly proportional to the current through that resistance. Therefore, by measuring the cow contact voltage, one is indirectly measuring the cow contact current.

**Cow Contact Voltage (Vcc)** – The AC, 60 Hz, rms, steady-state voltage across the 500-ohm resistor established in a cow contact area. A measurement protocol has been established by the PSCW for the correct set-up of a cow contact so that the value measured will be worst-case (i.e. the largest value possible).

**Current (I)** – An electrical parameter that measures the flow or amount of electrical energy past any single point in a conductor or conductive element per unit of time. The current may be AC, DC, or a mix of both in character. Current is one of the three parameters used in Ohm's Law (qv). Electrical current cannot exist without the push (force) of a source voltage. It takes non-zero energy to move the electrons, which are subatomic particles with mass. Any temperature above absolute zero will make the electrons active and vibrate, but not travel as a coherent current. A temperature difference can create a voltage and therefore a current as happens in a thermocouple. Current will only flow in a complete circuit. Its unit of measure is the Ampere (qv).

**Current Balancing Transformer (CBT)** - A device that is installed on a utility electrical system to foster a condition where current is balanced between the energized phase conductor(s) and the neutral conductor. This device must be protected from an open neutral condition, as that would force high levels of return current to flow through a limited number of grounding conductors, grounding electrodes and the earth, thereby raising neutral-to-earth voltages in the area to very high (unsafe) levels.

**Current Limiting Device** – An electrical device that allows a certain level of current to flow through it and interrupts that flow when the specified level is exceeded. Examples are fuses and circuit breakers (qqv). Electrical codes specify the conditions and situations where a current limiting device must be installed for reasons of safety. The specific rating of the device is crucial to the proper operation of the circuit it protects.

**Current Return Ratio (CRR)** – The ratio of the amount of current returning on the neutral conductor to that supplied by the phase conductor during a load box test (qv), usually expressed as a percentage. For a 7,200-

Volt primary system, the PSCW would like to see at least a nominal 66% return. For a 14,400 Volt or higher primary system, the PSCW would like to see at least a nominal 50% return. These numbers are only guidelines, as the amount of return current is affected by many parameters on the distribution system as well as the customer's grounding system that may not be easily controlled. The PSCW database indicates that, at the farm's transformer, the average return current is 70% through the neutral conductor and 30% through alternate conductive paths including, but not limited to, the earth.

**Cycle** – On a waveform of a continuous (analog) electric signal, one cycle is the basic unit of time to complete the wave shape, both positive and negative, which then repeats endlessly. For a 60 Hz electrical power system, one cycle lasts 16 and 2/3rds milliseconds. (See also degree, frequency, wavelength and Hertz)

**Data Acquisition System (DAS)** – A group of electrical devices or single integrated unit used to measure and record data from an analog electrical system. The DAS may measure several channels of voltage and/or current and usually stores the data in digital form by using an analog-to-digital converter (ADC) (qv). It may present all the data it records without modification or it may concentrate the data and show only a single representative value for many periods of data. It may record peak and calculate rms values or may actually determine true rms values. The DAS will have a 'sample rate' specified that determines the least time interval needed to acquire one point of data. It will not sample again until the next sample interval. This limits the upper frequency the DAS is able to accurately record. The number of digital bits that the DAS is designed to have will necessarily limit the accuracy of the converted signal. Because most DAS units have very high input impedance, the inputs are susceptible to noise and interference pick up.

**decibel (dB)** – A unit used to indicate the ratio of gain (amplification) or loss (attenuation) of an electrical signal. A dB is a ratio of gain or loss against a standard level or a measured level. The formula for conversion of a ratio to dB for voltage is  $\text{dB} = 20 * \log(\text{Vout} / \text{Vin})$  and for current is  $\text{dB} = 20 * \log(\text{Iout} / \text{Iin})$  and for power it is  $\text{dB} = 10 * \log(\text{Pout} / \text{Pin})$ . One of the levels may be a standard amount (i.e. 1 milliVolt or 1 microWatt). A level of 0 dB represents neither gain nor loss, while 3 dB of voltage or current is a ratio of the square root of 2 (which is 1.414) or its inverse (which is 0.707). Three dB of power is a 2 to 1 (or 1 to 2) ratio.

**Degree** – A subdivision of a single electrical cycle used for timing purposes in electrical work. By convention, there are 360 electrical degrees in one cycle. For a 60 Hz cycle, each degree lasts about 46.3 microseconds. Note that one quarter of a cycle (the maximum positive amplitude point) is 90 degrees, one half cycle is 180 degrees (a zero crossing point), three quarters of a cycle (the maximum negative amplitude point) is 270 degrees, and 360 degrees is the same exact point as zero degrees as the cycle repeats.

**Delta (Δ) System** – A configuration of a three-phase primary or secondary electrical system that does not employ a conventional neutral conductor. In transformers and loads, it takes the form graphically of an equilateral triangle. A delta wiring system will have three phase conductors and no neutral conductor. The advantage of a delta system is balanced loading, but the disadvantage is, if no phase wire junction is grounded for safety, an unintended grounding of a phase wire will be hard to detect and a second phase wire faulting to ground will create a very dangerous condition. Primary delta systems are more susceptible to damage from lightning strikes and system over-voltage conditions.

**Digital Multimeter (DMM)** – An electrical instrument, such as a Fluke 89, combining several measurement functions into one physical unit. In most cases, a DMM will be able to measure both AC and DC voltage and current as well as resistance. The more sophisticated DMM's have an auto-ranging (qv) capability. There are many specifications such as accuracy repeatability, precision, bandwidth, etc., as well as connection procedures for DMM's that must be thoroughly understood before the user may have confidence in the veracity and reliability of any measurement made.

**Digital Signal** – A signal that has been created to represent an analog signal (qv). The digital signal is the output of an ADC (qv). As such, a digital signal is a set of binary digits that have as close a representation to the original value of the analog signal at the time of its sampling as possible given the number of bits in the digital word. The number of binary digits designed into a DAS (qv) affects the precision to which any analog value may be represented. The maximum number of different combinations of binary numbers is calculated as the number 2 raised to the power of the number of binary bits. If, for example, only 6 binary bits per reading are designed, then only 64 ( $2^6$ ) different numbers can be representative of the reading using all available combinations of 6 binary bits. If 10 bits per reading are designed, 1,024 ( $2^{10}$ ) different values can be represented. If 12 bits per reading are designed, 4,096 ( $2^{12}$ ) different values can be represented. The maximum voltage divided by the number of possible digital values gives the expected precision of the instrument. A nominal 10-volt range on an instrument with a 10 digit ADC means each bit must represent about 9.766 milliVolts. No non-zero number can represent less and each single binary digit increase represents another 9.766 milliVolts. If we round this precision to 10 milliVolts, we can therefore conclude this unit cannot represent any voltage smaller than 10 milliVolts other than 0 milliVolts and can only have minimal increments of 10 milliVolts for each successive reading. That is, it cannot represent 0.015 Volts. It would either round this to 0.02 V or truncate it to 0.01 V.

**Direct Current (DC)** – A type of electrical energy that is characterized as being steadily on or off with little or no variation over time. For example, a DC voltage, and therefore a DC current, is produced by a storage battery. Most electrical devices convert AC voltages and currents to DC voltages and currents within their power supply sections. One can consider that DC signals are a special case of AC signals having a frequency of zero. Studies have shown that humans and animals are less sensitive to DC currents than to the same amplitudes of certain frequency AC currents.

**Distribution System** – A portion of the electrical power system that efficiently delivers energy to end-users. A generation system creates the force (voltage) that allows current to flow as needed. The uni-grounded transmission system steps up the generated voltage to levels that afford large amounts of energy to be carried over large distances with minimal loss. A distribution system connects to the transmission system at a substation and steps the voltage down to reasonably safe levels and thereafter connects it to each customer desiring energy service in a massively parallel (qv) circuit that is multi-grounded for safety, reliability and proper operation.

**Distribution Voltage Level** - The most common nominal levels for distribution in Wisconsin are 2,400, 4,800, 7,200, 13,800 and 14,400 Volt (measured phase to neutral) for single-phase systems and 4,160, 8,300, 12,470, 23,900 and 24,900 Volts (measured phase to phase) for three-phase systems. All voltages are AC, rms. Other levels may be used, but are less common.

**Earth** – The earth is considered the one, single basic reference point for the measurement of voltages. The earth represents a vast volume of low resistance material that can nearly infinitely source and sink electrical energy as needed by utility and customer electrical power networks to balance their systems (if all the electrons in the earth's crust were a part of one circuit, it is estimated the current would be about  $4 \times 10^{30}$  Amperes). A voltage measurement made to the earth well away from any electrical system or buried metallic structure is defined as being made to a zero-valued reference.

**Earth Current** – Once electrical current leaves the structure of a grounded object or made electrode to flow within the three dimensional soil structure of the earth itself, it becomes an earth current. The magnitudes of these earth currents, away from metallic objects in the earth, is usually very low because of the vast three dimensional structure of the earth. There are many naturally occurring currents in the earth at DC and many AC frequencies, as well as a wide range of man-made currents from utility, industrial, commercial, broadcast and customer electrical systems connected to the earth throughout the planet. Merely measuring current amplitudes and frequencies in the earth is usually not sufficient to determine its source.

**Electric field** – An electric field is a phenomenon produced by any non-zero voltage that exists apart from the earth. The field may be AC or DC or a combination of both. It is measured in volts per meter of distance. It can induce voltages and therefore currents to flow in metallic objects not otherwise energized. It is a relatively weak medium for the transfer of energy and is easily shielded. It is only possibly of concern directly beneath high voltage transmission lines.

**Electric Shock** - An amount of electricity that can be felt by a person or animal. This amount varies from the lowest level of perception to dire consequences at high levels. The amount of current and voltage necessary to be felt and to have some consequence varies for each person or animal and for each situation. The physical nature of the voltage and current are also crucial in whether a shock is perceived or has consequences. Experiments have shown that humans are more sensitive to AC frequencies of the 30 to 100 Hz range than to DC or to lower or higher frequencies at the same voltage level. In fact when the frequency is very high or duration extremely short, many times more voltage is needed for perception. (See also electrocution).

**Electricity** - A physical phenomenon in which charged particles are responsible for the transport of energy from one point to another. Electricity was first recognized by early Greek scientists. Electricity is well understood and can be quantized with mathematical models. Basic laws of electricity have been developed that have been proven to hold true even in distant galaxies! Electrical energy is extremely useful to humankind, but can be dangerous if not fully understood and treated with respect. Electrical energy can be transported by three methods: conduction, induction and radiation (qqv).

**Electrocution** – At high levels, exposure to electrical energy can cause injury and death to humans and animals. The amount of electrical energy needed to cause injury or death may vary among individuals as well as among individual animals within the same species. It depends on such things as body mass and configuration, body chemistry (conductivity), health condition, etc. One table lists the following conditions for shock and electrocution levels in humans:

EFFECT	DC		60 Hz AC	
	MEN	WOMEN	MEN	WOMEN
<b>Painful Shock (muscle control not lost)</b>	62 mA	41 mA	9 mA	6 mA
<b>Painful and sever muscle contraction</b>	90 mA	60 mA	23 mA	15 mA
<b>Possible Ventricular Fibrillation from Short Shocks</b>				
<b>Shock duration = 0.03 Seconds</b>	1300 mA	1300 mA	1300 mA	1000 mA
<b>Shock duration = 3 Seconds</b>	500 mA	500 mA	100 mA	100 mA

Fatal electrocution is at a level well above the basic level of perception and above the level of shock perception. Unless the heart is re-started to a proper rhythm after the onset of ventricular fibrillation, death will shortly ensue. The method of contact and the points on a body where the contact is made are vital in determining if the exposure to the electrical energy will result in fatal electrocution. Ohm's law combined with typical resistances for animals and humans can be used to determine the voltages that will produce the above currents.

**Electro-magnetic Field (EMF)** – A term used to describe both an electric field and a magnetic field that coexist in a given space. For an AC EMF, it can be represented by two sine waves traveling forward and at right angles to one another. For example, if the EMF wave is traveling into the plane of this paper, the electric field could be up and down on the sheet, while the magnetic field would be right and left on the paper. Most energy that travels through the air and space is in the form of EMF's. The electric field component is dependent on the magnitude of the voltage present and is measured in Volts per meter, while the magnetic field is dependent on the current present and can be measured in Gauss (qv). Radiated signals are broadcast from antennas via electro-magnetic fields. Any receiving antenna or antenna-like structure exposed to electro-magnetic fields will have electric signals coupled and induced upon it.

**Electro-magnetic Induction** – See induction.

**End-of-line Customer (EOL Customer)** – By definition of the PSCW, a customer is considered end-of-line if s/he is the last customer of a radial feeder or is on a tap at least 1/2 mile from a distribution line going in two different directions from the tap.

**Equipotential Plane (EPP)** – EPP's are an electrical industry standard method used to reduce the possibility of electric shock. They are also a method used to mitigate SV on-farm. EPP's are required by the NEC, with certain exceptions in Wisconsin. An EPP is created by physically bonding together all metal structures and reinforcement rods in concrete within a farm structure. These are then bonded to the ground/neutral system of the farm's electrical service. This action creates a low resistance network that cannot support significant differences in voltage no matter how much current may flow through it. EPP's must be designed such that any transition area from off the plane to on the plane has a low enough gradient of voltage that no step potential (qv) exists which exceeds the PSCW level of concern (qv).

**Filter Circuit** – A circuit designed to isolate or separate a band of frequencies from a signal that may have a wider range of frequencies. There are four basic filter circuits: hi-pass (passing only higher frequencies), lo-pass (passing only lower frequencies), band-pass (passing only frequencies within a designated range), and band reject (not passing frequencies within a designated range). Each filter can be designed for a specific bandwidth (qv) or cut-off frequency (frequency point where the filtering action occurs) and the amount of attenuation (qv) per range of frequency.

**Five-wire System** – A wiring method for electrical systems that have three-phase conductors. In this system, there are three phase wires, a uni-grounded neutral wire and a multi-grounded grounding conductor. On a farm in each sub-panel, the five wires are independent of one another. In the main distribution/disconnect panel, the neutral and grounding conductors are required by code to be bonded to each other and to be grounded.

**Floating System** – An electrical system that is not tied or bonded to the earth via a grounding conductor as a ground-referenced system (qv) would be. This type of system may function for the supply of energy to a load, but is inherently unsafe as this configuration may prevent the proper operation of current limiting devices (qv). It may also be subject to inordinate amounts of electrical outage due to lightning strikes. A multi-grounded electrical system is the surest and safest system to use for the transfer of electrical energy.

**Four Main SV Electrical Parameters** – The minimum electrical parameters that are recommended to be monitored during Phase I and Phase II stray voltage testing by the PSCW. They are: primary neutral end of the circuit to reference voltage ( $V_{pnref}$ ), secondary neutral end of the circuit to reference voltage ( $V_{snref}$ ), voltage drop between primary and secondary neutrals ( $V_{ps}$ ), and cow contact voltage ( $V_{cc}$ ) (qqv).

**Four-wire System** – A wiring method for secondary electrical systems that have single (bi-) phase (120/240 V.) service. In this system, there are two phase wires, a uni-grounded neutral wire, and a multi-grounded grounding conductor. At each sub-panel, the four wires are independent of one another. In the main disconnect panel, the neutral and grounding conductors are bonded to each other and are grounded.

**Frequency** – The property of an AC electric signal that specifies how many waveforms (full cycles) per unit of time there are in a voltage or current (i.e. cycles per second or Hertz(qv)). The power in the US is at a frequency of 60 Hertz (Hz). In Europe and many other foreign countries, it is 50 Hz. In general, AC signal frequencies may exist from sub-Hertz to many GigaHertz (1 GigaHertz = 1,000,000,000 Hertz). Frequency is proportional to the inverse of wavelength (qv), in fact they are related by the formula: frequency (f) equals the speed of light (a constant value called 'c') divided by the wavelength ( $\lambda$ ) (or  $f = c/\lambda$ ).

**Frequency Modulation (FM)** - A type of modulation in which a carrier frequency (a single frequency AC wave) changes its frequency in response to the modulation of an audio signal at a radio station. It maintains a relatively constant amplitude. The FM radio signal is much less susceptible to noise interference compared to an AM radio signal (qv). The standard broadcast band for FM signals in this country is 88.1 MHz to 107.9 MHz with a station assignment every 0.2 MHz (100 different channels). The allowable bandwidth of audio signals is about 20 KHz and the output power generally ranges from 100 Watts to 100 kW per station. There are 8,032 commercial FM stations within the US. Television stations also use a combination of frequency modulation and amplitude modulation for their audio and video signals. There are 1,663 commercial TV stations within the US broadcasting on frequencies from 54 MHz to 800 MHz and with radiated powers up to 5 MegaWatts per station. FM radio signals can be a form of noise to measurement processes that have ungrounded conductors that act as antennas.

**Fully Jacketed Cable** – A type of directly buried primary distribution cable that has all its conductive elements, phase and neutral, covered by an overall non-conductive jacket. Per NESC code, the jacket is opened at intervals such that the neutral conductor can be effectively grounded at least four times per mile of cable.

**Fundamental Frequency** – The lowest frequency of a multi-frequency electrical signal. Usually used in conjunction with power quality terms. When harmonics are present, they are integer multiples of the fundamental frequency and are always an integral part of the fundamental waveform. They are never found separate from it without the specific intervention of a device like a filter circuit (qv).

**Fuse** – An over-current protective device that is rated to pass a certain number of amperes of current. If the current level exceeds the rating, the fuse element melts and that interrupts the circuit for safety. The higher the over-current, the faster the fuse melts. For safety, always replace a fuse with the same type of rating, physical size and characteristics.

**Galvanic Effect** – A natural process that creates various DC voltages and currents through an electro-chemical interaction. Whenever two dissimilar metals are in the presence of an electrolytic fluid, they will generate a specific DC voltage between them, depending on which metals are present and the concentration of the electrolyte. In a barn environment that is full of dissimilar metals and very strong electrolytic fluids (urine, water with feces in it, etc.), these voltages are very easily measured and are usually characterized by having very low energy content.

**Gauss** – The unit of magnetic field intensity measurement. Like the Ampere, it represents a relatively large quantity of magnetic field intensity. Engineers and scientists usually use the milliGauss as the basic unit. This is  $1/1,000^{\text{th}}$  of a Gauss. The background level of magnetic field in most homes and barns is in the level of one to five milliGauss. Nearing a active electrical appliance, the magnetic field can rise dramatically to levels of 100's of milliGauss. Most exposure levels for determining adverse effects to magnetic fields use a test level of 1 Gauss (1,000 milliGauss) magnetic field strength. Another very large unit of measure of magnetic field strength is known as the Tesla, therefore the microTesla ( $1,000,000^{\text{th}}$  of a Tesla) is commonly used. The conversion is one milliGauss = 0.1 microTesla or 1 microTesla = 10 milliGauss.

**Gaussmeter** – An electronic instrument used to measure magnetic field strength. Some of these instruments measure the magnetic field strength in only one direction, while others measure a composite field strength in three mutually orthogonal directions (x, y, and z). Some instruments are constrained to measure 50/60 Hz magnetic fields, while others will measure a wider range of frequencies.

**Generation System** – An electrical system that converts the energy of heat or motion into electrical energy. The generator may be powered by many different mechanical or chemical sources such as hot steam created by the combustion of natural gas, coal, fuel oil or nuclear material disintegration, or by wind, falling water or tides. The usual type of electricity generated is AC in a three-phase wye configuration (qv).

**Giga- (G)** – A numerical prefix meaning 1 billion, i.e. 1,000,000,000.

**Ground** – A term used in electrical science meaning the point of lowest potential for an electrical system. A floating system (qv) may have a ground part of the circuit that is not referenced (conductively connected) to the earth. In most circuits, the earth is used as a ground for current return and voltage reference. As a verb, to ‘ground’ a part of an electrical system means to provide an electrically conductive path to the ground and/or earth system.

**Ground Current** – Referring specifically to that current of an electrical system that is on a grounding conductor, a grounding electrode, or some other conductive pathway between the neutral (grounded) conductor and the earth apart from that which is physically on the neutral conductor. Once a current leaves the grounding system and goes into the earth, it becomes an earth current (qv).

**Ground Loop** – When an electrical ground system is connected to the earth at many points, a parallel current path is created. When a circuit loop is created in this fashion, it is referred to as a ground loop. This ground loop may have voltages and currents induced on it from air-borne electro-magnetic fields or from nearby current carrying conductors. It may also radiate EMF energy from the circuit it is a part of. Any currents flowing in the ground loop can cause induction currents in other separate circuits. These induced currents and their associated voltages, when at sufficient levels, may interfere with the operation of any electrical system the ground loop is a part of.

**Ground-Referenced System** – A system that has all its basic voltage measurements referenced to a grounding (earthed) system, as opposed to a floating system (qv). Ground referenced systems are safer to work on and usually are more reliable to operate than floating systems.

**Grounded Conductor** – In a typical primary or secondary power delivery system, there are three basic types of conductors (1) phase or hot conductors (qv), (2) a grounded conductor, also known as the neutral conductor, and (3) a grounding conductor (qv) which connects the grounded conductor to the earth at specific points per the NEC and NESC (qqv).

**Grounding Electrode Conductor** – A conductor that normally does not carry full load current but is designed to carry fault current in emergency conditions for safety reasons. On a secondary electrical system, this conductor should be bonded to all the metallic enclosures and non-current carrying metallic elements of the branch circuit it is a part of. Also, it is defined as a conductor that is designed to connect a grounded neutral bus bar to a grounding electrode element. On an operating electrical system and/or where there are multiple connections to the earth separated by some distances, there will always be some incidental current, both inductively and/or capacitively coupled and directly conducted, on the grounding conductors.

**Grounding Electrode** – Usually, a driven ground rod or system of multiple parallel ground rods that connects a grounded neutral system to the earth via a grounding conductor. In cases where multiple ground rods must be driven, they are connected in parallel with appropriate hardware and wire designed for the purpose to achieve an effective grounding electrode system. In general for buildings, a single driven rod must be 25 Ohms to ground or less. If this condition is not met, a second ground rod must be driven and connected in parallel to the first. In Wisconsin, all one- and two-family dwellings automatically require two made ground electrodes. Continuous metallic water piping systems and other like systems are also effective grounding electrodes and are required to be bonded to this system if available.

**Harmonic** – When an electric power system is furnishing voltage to a non-linear load, current is not drawn in a smooth sine wave fashion, but in chunks and gulps during the power cycle. This causes the current to have harmonic content (be distorted from the pure sinusoidal wave shape) and therefore the supply voltage will also have harmonic content. Harmonics, integral multiples of the fundamental frequency, are a

mathematical contrivance that explains the shape of the distortion of a particular waveform created by the non-linear load. For any non-sinusoidal waveform, mathematics known as Fourier Transforms can be used to analyze or recreate the waveform as a fundamental plus various percentages (with phase relationships) of integral multiples of the fundamental waveform. For example, a waveform may be exactly described as 100% fundamental (60Hz) plus 1.2 % third harmonic (180 Hz) plus 0.5% of the fifth harmonic (300 Hz) and 0.4% of the seventh harmonic (420 Hz). The absolute amplitudes of each would be 120 V. rms fundamental, 1.44 V rms third, 0.6 V rms fifth, and 0.48 V. rms seventh. Harmonic frequencies are not found separate from the fundamental 60 Hz wave.

**Hertz (Hz)** – The basic unit of frequency equivalent to the number of electrical cycles per second.

**Horsepower (hp)** – The English measure of power equivalent to 745.7 Watts. This term is usually used to rate the power of electric motors and generators.

**Impedance (Z)** – The AC equivalent to the DC concept of electrical resistance (qv). The impedance of a network may contain both a resistive component and a reactive component that is dominated by either a capacitive or an inductive (qqv) element. Impedance is used in Ohm's Law calculations involving AC quantities. Impedance is a vector (qv) quantity (implying an associated phase angle). Only pure capacitances and inductances do not contain a resistive component within the impedance.

**Induction** - One of three physical methods for the transfer of energy by electricity. In this method there are two scenarios for energy transfer. In the first, a current is generated onto a conductor that moves at some non-zero angle to a magnetic field. This is the process that allows electric motors and generators to function. The second is where a fixed conductor is in the presence of a changing magnetic field. This process allows transformers to function. Any time a noise or interference signal produces a voltage in a conductor that it is not directly connected to, it is usually via the induction process. For example, envision the case of two parallel conductors. They are not physically connected at any point and are parts of separate circuits, but are in close proximity. The first conductor is a phase conductor that carries an AC current to a load. This creates a changing magnetic field that concentrically surrounds the conductor. The second conductor is in the presence of that changing magnetic field and will, as a consequence, have an AC current induced within it. The induced current is usually much attenuated compared to the coupling signal. The other methods for the transfer of energy by electricity are radiation and conduction (qqv).

**Inductor (L)** – A circuit component used in AC systems. It can be considered the opposite of a capacitor. While an inductor will pass both an AC and a DC current, it resists the flow of AC currents more as the frequency of the AC waveform is increased. Generally any solenoidal-wound coil of wire acts as an inductor. This inductor may have an air core or a core made of magnetic material that concentrates the magnetic flux surrounding the solenoidal windings much more efficiently than air does. AC motor windings are essentially a coil of wire, so they are inductive, as are transformer windings. Even a straight wire has some minimal inductance.

**Input Impedance** – An important property of an electrical network, specifically a DMM, oscilloscope or DAS (qqv). When input impedances are low, they may affect the accuracy of the measurement of voltage. It is usually desirable that the input impedance of a voltage-measuring device be greater than 1 MegOhm, ideally greater than 10 MegOhm. The drawback to high input impedance is, when very long, non-shielded leads are used to connect to a voltage measurement point, a lot of inductive and capacitive pick up noises and interferences are also acquired. One should always use the manufacturer's supplied leads for any high input impedance DMM or DAS when the bandwidth of the measured signal is not otherwise controlled.

**Insulator** – A class of materials that does not readily support the flow of electricity. Such materials are characterized by having very high resistances or impedances (many powers of ten above the MegOhm range). Examples are dry air, glass, certain plastics and ceramics, etc.

**Interface** – When two independent electrical systems are connected together, they are said to be ‘interfaced’. When proper interfacing is to be accomplished, much consideration needs to be made of the effect of one system upon another. Well-designed interfaces provide for little degradation in signal amplitude, frequency, impedance, waveform shape, etc.

**Interference** – When an electrical measurement is taken, there may be spurious interferences or noises generated by some other generation source that is measured along with the signal. In some instances, the power supply of one’s own DAS instrument may be the source of interference. Sometimes the interference can be cancelled or filtered out to lessen its impact on the signal. Sixty cycle interference is so common, it is given its own name: ‘hum’. A full understanding of the measurement process, instruments and circuits involved must be used to properly interpret any data measured. It is generally improper to claim interference and noise as signals. (See signal to noise ratio)

**Investor-owned Utility (IOU)** – A for-profit utility that is owned by investors through stock purchase. In Wisconsin, there are 5 large and 6 small IOU’s. They are all under the regulative authority of the PSCW.

**IR drop** – a term used in Ohm’s Law ( $qv$ ) to denote the fact that anytime a non-zero current flows through a non-zero resistance, a voltage drop ( $qv$ ) must develop. This voltage drop is the same as the IR drop.

**Isolation Transformer** – A transformer that does not have the primary neutral terminal conductively connected to the secondary neutral terminal. Each neutral must be grounded to the earth for safety, but the grounding is independent. Since the metallic frame of this transformer might become energized at high voltage levels during a fault condition, isolation transformers must be mounted on a non-conducting (wooden) pole system at least 8 feet in the air for safety. The amount of isolation (the attenuation of the primary neutral to reference voltage measured on the secondary side of isolation) is about the same as for a neutral isolator device ( $qv$ ). In no case shall the system be designed or implemented such that the earth becomes the sole fault current path. Because these devices use AC current to energize their magnetic cores for their operation, they may consume appreciable power that is continuously expended as waste heat.

**Johnson Noise** – Also known as thermal noise, it is one of the most prevalent sources of electrical noise known. At any temperature above absolute zero (the coldest possible temperature of all), heat causes all subatomic particles, atoms, and molecules to vibrate. This vibration manifests itself as a small, but not insignificant, noise within all electrical systems. When a person interpreting an electrical measurement does not take this common noise source into account, an error may result. (See also interference and noise).

**K-factor** – A number useful in SV analysis. It is formally defined by the PSCW as the ratio of cow contact voltage ( $V_{cc}$ ) to secondary neutral-to-reference voltage ( $V_{snref}$ ) made during a load box test. The PSCW uses a guideline of 33% to 50% as being a desirable number, but not a strict limit. It is often found that numbers calculated greater than this may indicate that the reference rod location is too close to the electrical system under test. When conditions dictate the reference rod should be relocated, a retest should be performed. In essence, the K-factor indicates how tightly coupled the voltage in the cow contact area is to the neutral voltage of the farm’s electrical service.

**kilo- (k)** – A numerical prefix denoting 1,000. An example is a kiloWatt meaning 1,000 Watts.

**kiloVoltAmpere (kVA)** – A unit of measure for the power rating of transformers. A kVA is 1,000 Volt-Amperes. When one multiplies the voltage rating and the current rating of either the primary side or the secondary side of a transformer and divides by 1,000, the kVA rating is established. For example, a transformer primary rated for 7,200 volts and drawing 5.21 Amps at full load is rated 37.5 kVA. Most dairy farms in Wisconsin should have at least a 25-kVA transformer to provide power for their loads.

**Kirchhoff's Current Law (KCL)** – An electrical circuit relationship developed to analyze circuits using currents. This law deals with nodes. A node is defined as the junction of two or more circuit paths that may carry an electrical current. No circuit element may be within a node. A practical example is a number of wires stripped of their insulation and joined together with a wire nut. This creates a node. Note that no electrons could possibly be stored by such a node. The law states, in essence, that the signed sum of all currents entering a node equals the signed sum of all currents leaving a node. By stating it this way, the algebraic sum of all currents at a node is zero. For example, a three-path node has currents entering of 2 and 3 amps. The current leaving must be 5 amps, as no other path is available and the electrons cannot be accumulated in the node. Also note that all currents cannot simultaneously only enter or simultaneously only leave the node. This law implies that ‘all currents must return to their source’. This is true because in order for a current to flow in the first place, a closed loop complete circuit must exist. Since no current can be stored indefinitely in any element or node, it must flow back to its source.

**Kirchhoff's Voltage Law (KVL)** - An electrical circuit relationship developed to analyze circuits using voltages. This law deals with complete circuit loops. A circuit loop allows a current to leave a source, travel on a conductor through various circuit elements in series or parallel, and return to that source via another conductor. If no complete closed circuit loop exists, one cannot use this law to analyze the circuit. The law states that the signed sum of all voltage sources must equal the signed sum of all voltage drops (IR drops) (qqv) around the loop. For example, a 10-Volt source allows 2 Amps of current to flow through a series circuit consisting of two resistors of 2 Ohms and 3 Ohms, respectively. The current is allowed to return to its source. The voltage drop or IR drop, from Ohm's Law for each resistance, is 4 Volts and 6 Volts respectively. Their sum is 10 Volts, which equals the source voltage. They must agree, since no other voltage drop can exist (since no other circuit resistance is specified) and no other voltage source exists in the circuit as described.

**Least-significant Bit (LSB)** – In a digital system of more than one bit, there is a designated bit that represents the least change as one increases from one digital quantity to the next sequential digital quantity represented by the digital number. The LSB means the weight of that least bit. For any digital system with  $n$  bits, the greatest representative digital expression is  $2^n - 1$ . (A 12-bit system has  $2^{12} - 1$  or  $4096 - 1 = 4095$  as the maximum digital representation and 0000 as the minimum digital representation.) For example, in a system where a maximum of 128 Volts is to be represented by 12 bits, the LSB would mean a minimal increment of 0.03125 Volts ( $128/4096$ ). That is to say, the first binary number means 0.00000 Volts, the next means 0.03125 Volts and the next means 0.06250 Volts, etc. until all 4,096 binary numbers are used, the last one representing 127.96875 V.

**Level-of-concern (LOC)** – In Wisconsin, the present “level of concern” is derived from the 1996 PSCW docket 05-EI-115. The LOC is formally defined by the PSCW as 2.0 milliAmps, AC, rms (root mean square), steady-state (qqv) or 1.0 volt, AC, rms, steady-state across a 500-Ohm resistor in the cow contact area. The state of Wisconsin deems that this level of voltage/current is an amount of electricity where some form of mitigative action is taken on the farmer's behalf, although only some small percentage of cows may actually perceive its presence. The “level of concern” is not a damage level. Instead, it is a very conservative, pre-injury level, below the point where moderate avoidance behavior is likely to occur and well below where a cow's behavior or milk production would be harmed. The “level of concern” is further broken down into two parts. The first part is a 1.0-milliAmp contribution from the utility, at which level mitigative action must be taken by that utility to reduce its contribution to below the 1.0-milliAmp level. The second part is a 1-milliAmp contribution from the farm system, at which level some form of mitigative action should be undertaken by the farm operator.

**Load Box Test (LB test)** – A test that is part of the PSCW Phase II (qv) test protocol. This test is used to help determine the amount of utility contribution to any cow contact voltage/current exclusive of any contribution from on-farm sources. In this test, all farm loads are disconnected from the electrical system. The primary transformer has a 240-Volt resistive load box of 18 to 25 kW size connected to it. Various

currents and voltages are measured to determine if the utility system has the ability to contribute 1 milliAmp of current or more to the cow contact area under the maximum proxy load of 18 to 25 kW.

**Load Device** – A device connected to an electrical system that supplies energy to it to do some form of useful work. Some characteristics of the load are its impedance: resistive, inductive or capacitive, the instantaneous power drawn in Watts, its power factor, its basic voltage and current ratings, its linearity, and its starting and operating characteristics, if applicable.

**Magnetic Field** - Whenever an electric current flows, a magnetic field is created. The stronger the current, the stronger the magnetic field will be. Static magnetic fields are also produced by such things as permanent magnets and DC currents. The magnetic field around a point on a conductor can be envisioned as a set of concentric circles existing from just above the conductor's surface to infinity. The strength of the magnetic field decreases with distance from the conductor's surface. AC magnetic fields vary in time at the same frequency as the AC current that creates them. One can envision this as a moving set of concentric rings pulsating large and smaller about the conductor at the frequency of the AC current. Magnetic fields are measured in Gauss (qv).

**Main Disconnecting Means** – An electrical switch that allows all electric service beyond the device to be manually interrupted when needed. The main disconnecting means may or may not have over-current device (qv) protection.

**Mega- (M)** – A numerical prefix denoting 1,000,000 as in MegaOhm (or MegOhm) meaning 1,000,000 Ohms.

**Micro- ( $\mu$ )** – A numerical prefix denoting 1 millionth ( $1/1,000,000$ ) as in microVolt meaning one millionth (0.000001) of a Volt.

**Milli- (m)** – A numerical prefix denoting a thousandth ( $1/1,000$ ) as in milliAmp meaning  $1/1,000$  or 0.001 of an Ampere.

**Multi-grounded System** – The system of electrical distribution used in this country in which the neutral circuit is tied at distinct intervals to the earth for reasons of safety, lightning protection, and proper system performance. The NESC calls for a minimum of four earth connections per mile of system. Wisconsin has always specified nine grounds per mile and the PSCW has recently required a ground at every pole in new rural construction.

**Municipal Utility (muni)** – A not-for-profit utility owned and operated by a municipal entity. There are 82 such utilities in Wisconsin ranging in size from about 360 to 17,000 customers. These utilities serve an aggregate total of over a quarter million Wisconsin customers. These utilities are regulated by PSCW rules.

**Nano- (n)** - A numerical prefix denoting a billionth ( $1/1,000,000,000$ ). For example, a nanosecond means 1 billionth part of a second (0.000000001 second). As an example of how small this is, if one second is represented by one million dollars, one nanosecond would be one tenth of a penny (one mill)! Another example is how far light travels in one nanosecond. The speed of light is about 186,000 miles per second, so a particle of light will travel just one foot in one nanosecond.

**National Electric Code (NEC)** – The electrical code that covers the wiring and system on the customer's side of the meter. This code is not a design manual, but contains the **minimum** standards necessary to make the utilization of electrical energy safe from both a fire and shock perspective.

**National Electric Safety Code (NESC)** – This code covers the wiring, equipment, and system on the utility side of the meter. Again, it is not a design guide, but a **minimum** safety standard for generation, transmission and distribution systems (qqv), especially for those individuals who work on these systems.

**Neutral Conductor** – A conductor designed to carry current returning from a load. In most electrical systems, it is a grounded conductor. This conductor must be connected to earth (be grounded) for safety, reliability, and system performance reasons. Because of its connection to the earth, it may not carry 100% of the return current. Load box testing on over 200 Wisconsin farms reveals that the average current return for single-phase systems at the farm transformer is 70% on the neutral conductor and 30% through other parallel paths including, but not limited to, the earth. For three phase systems, the current return ratio is much higher due to the balanced nature of that type of system.

**Neutral Current** – The current found in the neutral conductor. When this conductor is connected to the earth via a grounding conductor, that portion of the neutral current that flows down the grounding conductor structure is known as ground current (qv). When that current leaves the grounding electrode system and enters the earth, it becomes an earth current (qv).

**Neutral Isolator Device** (Electronic switch) – An electronic device designed to separate the conductive electrical connection of the primary and secondary neutrals on a farm. One could simply forego the wiring of these together, but that would create an intolerable safety hazard. Both neutral systems must be connected to the earth for safety reasons. By disconnecting them without a neutral isolator device in place, the earth becomes the sole fault current path for certain fault conditions. This condition is not allowed by either the NEC or the NESC (qqv). The physical neutral isolation device contains circuitry to nearly instantaneously reconnect the two neutrals should either of them rise above about 26 Volts from earth reference. The isolated condition returns when the neutral voltages return below the trip threshold. (See also Variable Threshold Neutral Isolator Device.)

**Neutral to Earth Voltage (NEV)** – The voltage between the neutral conductor and the (remote) earth of either the primary or secondary neutral system. When measured at the farm's main transformer to a remote reference rod, this voltage is known as primary neutral to reference voltage (qv). When measured at the farm's main grounded service entrance panel, this voltage is known as secondary neutral to reference voltage (qv). Despite the fact that neutral conductors are grounded (earth assumed to be at zero potential), some non-zero neutral voltage to earth exists. The overall average NEV in rural areas of the state is about 1.0 to 1.3 V.

**Noise** – Electrical measurements (signals) are subject to unwanted interferences known generally as noise. Noise is omnipresent in all real-world measurements. Its source may be man-made or natural. Electrical noise may enter into a measurement process by conduction (ohmic contact), induction (inductive coupling), radiation (EMF coupling), capacitive coupling, ground loop pick-up, physics (Johnson noise) (qqv) or a combination of each. The opposite of noise is signal (qv).

**Non-linear Load** – An electrical load that takes current in bites or gulps and not in a smooth, continuous sine wave fashion. Most modern power supplies in appliances, computers, or office and industrial equipment are non-linear, as are certain newer motor drives. Non-linear loads are responsible for harmonic (qv) distortion of voltages and currents. Non-linear systems cannot be analyzed by the superposition (qv) theorem.

**Off-farm** – Any part of the electrical system beyond the farm's main transformer.

**Ohm's Law** – The most basic law governing the phenomenon of electricity. The DC version of this law can be stated three equivalent ways:

- (1) A voltage (in Volts) is created by a current flowing through a resistance. The voltage across that resistance is the product of the current (in Amperes) times the resistance (in Ohms).  $\{V=I \cdot R\}$
- (2) A current (in Amperes) is equal to a voltage (in Volts) divided by a resistance (in Ohms) that the voltage is across.  $\{I=V/R\}$
- (3) A resistance (in Ohms) is equal to a voltage (in Volts) across that resistance divided by a current (in Amperes) through that resistance.  $\{R=V/I\}$

Because AC systems involve a frequency component and are calculated using vector mathematics, Ohm's Law for AC systems can be much more complex, which belies the formula  $V = I \cdot Z$ .

**Ohmmeter** – A device used to measure electrical resistance. The measurement must be made on an un-energized circuit. To measure very low resistances, a special measurement circuit is used.

**On-farm** – Any part of the electrical system on the load (farm) side of the farm's main transformer.

**Open Wye-Open Delta** – A three-phase power delivery system that uses two primary phase conductors and a neutral conductor to power two transformer primaries. This is a way of providing three-phase power with the elimination of one transformer, but at the cost of a less well-regulated service voltage and an increase in current drawn.

**Oscilloscope** – An electronic instrument used to essentially draw a graphic representation of voltage and/or current with respect to time on an X-Y display. The output display usually shows the voltage or current amplitude on the Y (vertical) axis and time on the X (horizontal) axis. There are many design parameters that the operator of an oscilloscope must be familiar with in order to properly control the instrument and interpret the display. One can consider the modern digital oscilloscope as a DAS (qv). In an oscilloscope, an analog voltage signal is digitized by an ADC (qv) and the analog representation of that data is recreated on the display through a reverse digital-to-analog process. Since most oscilloscopes have the data manipulated by a computer software program, the instrument's designers may make some assumptions or take some short cuts before displaying the information to the user. This may help or hinder the proper interpretation of the data. One must know the electrical and operational specifications of the specific oscilloscope being used to properly interpret the display. Like most DAS systems, most oscilloscopes generally have high input impedance (qv) making them subject to noise and interference pick up.

**Other Electrical Phenomena (OEP)** – A classification used to designate electrical phenomena of concern to the farm community other than that which is defined herein as Stray Voltage. This may include earth currents, EMF, DC currents, high frequency currents, and transient events.

**Over-current Device** – An electrical device such as a fuse or circuit breaker (qqv) that is employed to protect the users of electricity from the potential shock and electrocution hazards arising from fault conditions through the quick disconnection of source voltages. The NEC and NESC specify where these devices are required to provide safe and efficient system operation.

**Parallel Circuit** – An electrical circuit where all elements are in parallel with one another. In this type of circuit, all elements share a common voltage while having individual currents for each element. An example is the power wiring within a house. All outlets are in parallel allowing any load plugged in to draw its own current from a common 120 V. rms AC source voltage.

**Parallel Resistors** – An equivalent single resistance can be calculated for any number of parallel resistors by adding the arithmetic inverse of each resistance for all the resistors in the circuit and then inverting the sum (i.e.  $1/R_{total} = 1/R_1 + 1/R_2 + 1/R_3 + \dots + 1/R_n$ ).

**Peak (pk)** – A method of describing the instantaneous point on an AC waveform where the measured voltage or current is at a maximum deviation from zero during a cycle. A peak reading implies ‘zero to peak’. For uniform repetitive waveforms, this is half the peak-to-peak (qv) reading. To obtain an rms value from the peak value of a non-distorted sinusoidal waveform, multiply the peak value by 0.707.

**Peak-to-Peak (pp)** – A method of describing an AC waveform where the measurement of voltage or current is from the most negative to the most positive value during one complete cycle. For uniform repetitive waveforms, dividing peak-to-peak values by two results in peak (qv) values.

**Phase Conductor** – A conductor that is designed to carry current (electrical energy) to the load device. If a system has no neutral conductor, then all current carrying conductors are phase conductors.

**Phase I Protocol** – A PSCW method of first time on-farm stray voltage testing to determine initial levels of cow contact voltage and possible sources. First time investigation data is submitted semiannually to the PSCW.

**Phase II Protocol** – A comprehensive test strategy designed by the PSCW and used to determine all sources of cow contact voltage both from on-farm as well as off-farm sources. There are five specific tests, as well as an overall data record form. The five tests are: (1) the load box test, (2) the secondary neutral voltage drop test, (3) the signature test, (4) the primary profile, and (5) the twenty-four hour test (qqv). Other tests may be performed as necessary to give a complete account of the electrical activity on the farm..

**Potential Difference** – An electrical term used in the same way as voltage or IR drop (qqv). A potential difference, measured in Volts, is the subtraction of a lower electrical potential as measured to zero reference (earth) from a higher electrical potential as measured to zero reference. This results in a positive quantity of potential difference.

**Power Factor (PF)** – A term used in AC electrical circuits to describe the ratio of active power to apparent power. In AC systems, there can be a phase difference between the voltage and the current. When the voltage and current waveforms from a source or load are in phase (overlapping or congruent waveforms), they’re said to have a PF of 1 or 100%. Purely resistive loads will have no phase difference between the voltage and current. For other loads, as the current gets more and more out of phase with the voltage, the PF number will decrease to the limit of zero when the current is 90 degrees out of phase with the voltage. This will occur when the load is purely capacitive or purely inductive. The current may either lead the voltage in time or it may lag the voltage in time depending on the character of the electrical system. In capacitive systems, voltage lags current; in inductive systems, current lags voltage.

**Power Quality (PQ)** – Any power concern manifested in voltage, current or frequency deviation that results in failure or mis-operation of customer equipment. From IEEE 1100-1992: The concept of powering and grounding sensitive electronic equipment in a manner that is suitable to the operation of that equipment. This may refer to over-voltage conditions (surges), under-voltage conditions (sags or brownout), no voltage conditions (blackout), transient voltages (spikes, dropouts, ringing), harmonics, frequency variations, flicker conditions, etc. Power quality is always measured within the electrical system as to its effects on sensitive electrical components and equipment and is by definition not a measure of electrical exposure to humans or animals.

**Power Transfer Switch** – A large switch able to select an input power source of either the utility system or a backup generator. When in that latter position, no generated back up voltage/current should access the utility system.

**Precision** – A number (usually a percentage) used to characterize how far from a nominal or ideal value the real value of something is. In the electrical industry for example, a resistor may be purchased in several

precisions or tolerances (qv). The norm is  $\pm 5\%$ , but they can be purchased in  $\pm 10\%$ ,  $\pm 2\%$  and  $\pm 1\%$  grades. Capacitors on the other hand are normally in the  $\pm 20\%$  precision range with a high premium paid for  $\pm 5\%$  or  $\pm 1\%$  grades. For instruments, an overall precision or accuracy is often specified such as  $\pm 2\%$  of reading + 1 digit of a digital display. Thus, if a reading of 0.490 volts is made on such a DMM having a three-digit display and on the 1-Volt (.999) scale, the true value could conceivably be between 0.479 Volts and 0.501 Volts (i.e. anywhere within a 22-milliVolt range).

**Primary Electrical System** – A term that describes the utility electrical system including the generation, transmission, and distribution systems (qqv).

**Primary Neutral to Reference Voltage (V<sub>pnref</sub>)** – The voltage that exists between the primary grounding electrode/grounding conductor point of the farm's main transformer and a remote reference rod. The grounding electrode is connected to the primary neutral at the transformer via the grounding electrode conductor.

**Primary Profile Test** – A test specified by the PSCW Phase II protocol where nearly simultaneous readings of primary system grounding current and ground rod system resistance are made. These readings are taken for all grounded primary distribution poles for  $\frac{3}{4}$ ths of a mile on each side of the farm's tap pole (qv). From this data and using Ohm's Law, a primary neutral to earth voltage profile can be calculated for each pole. This data is useful in analyzing the character and capabilities of the distribution neutral/ground system in the vicinity of the farm.

**Primary Underground Conductor** – A conductor or cable that carries the utility service electrical power underground instead of overhead. It is rated for the primary line voltage that it is energized to and for the amount of expected current it must carry. The cable may be either fully jacketed or have a bare concentric neutral (qqv).

**Protocol** – An important concept used in testing, such as for stray voltage testing, meaning a formal set of conventions governing a process. With a defined protocol, all quantities to be measured, all connection methodologies, and all instrument types and specifications are published so that anyone wishing to duplicate the test may do so with a high degree of confidence that his results will be comparable to others' results and will be statistically significant. Without such a protocol, one has the apples and oranges comparison milieu dreaded, and hopefully avoided, by all.

**Quarter-wave Antenna** – An antenna whose minimum length ( $\frac{1}{4}$  of a wavelength (qv) or 90 electrical degrees) is tuned or adjusted to maximize its ability to receive or broadcast a specific frequency electrical signal of interest. One end of the antenna is grounded and the other has a maximum signal radiated or received. Half integer multiples ( $\frac{3}{4}$ ,  $\frac{5}{4}$ ,  $\frac{7}{4}$ ,  $\frac{9}{4}$ , etc.) of this length also have the same property. For example, if one were to receive a 60 Hz signal by this antenna, it would be just over 770 miles in length. For a 10 MegaHertz frequency signal, the quarter-wave antenna length is about 25 feet (7.5 meters). Conversely a 7.5-meter antenna is a quarter-wave receptor for 10 MHz, 30 MHz, 50 MHz, 70 MHz, 90 MHz, etc frequency signals. Unshielded instrument leads can act as quarter-wave antennas for the reception of unwanted noise and interference voltages.

**Radiation** - One of three physical methods for the transfer of energy by electricity. In this method, electrical energy is broadcast through air or space as electro-magnetic (EM) waves. This may be inadvertent, as the broadcast generation of noise or interference, or may be purposeful, as the broadcast of radio and television signals. The other methods for the transfer of energy by electricity are conduction and induction (qqv).

**Radio-frequency (RF)** – A broad term referring to a spectrum of frequencies above 10 kiloHertz and more usually above 100 kiloHertz. The upper limit is generally 100 GigaHertz, but is sometimes extended to 3,000 GHz. The upper part of this band is known as microwave or millimeter wave frequencies. The next

energies beyond this band are known as the infrared and then the visible light spectrum. Radio frequency waves propagate electrical energy via electro-magnetic (EM) radiation (qv). The transmission of frequencies in the range of 10 kHz to 3 MHz have both an 'air wave' component and a 'ground wave' component meaning the earth is an intended conductor for these energies. Man-made signals and naturally-occurring noises exist at nearly all radio frequencies.

**Reference Rod** – A metal rod driven into the ground and used as an earth reference point for the measurement of voltages (or potential differences) on a ground-referenced electrical system (qv). The rod is usually driven about two feet into the ground at a point well away from any electrical system grounding electrodes and away from any other buried metallic structure. When properly placed, a voltage measured between the reference rod and any point on the electrical system will represent a measurement to true zero reference potential.

**Resistance (R)** – An electrical quantity that quantifies a physical material's ability to conduct or not conduct electricity. It is one of three parameters used in Ohm's Law (qv). It is measured in the unit of Ohms. In general terms, resistances up to the range of 100 or so Ohms represent a good conductor. Moderate conductors range from 100 Ohms or so to perhaps as much as 100,000 Ohms. Poor conductors range from about 100,000 Ohms to perhaps as high as several hundred MegOhms and insulators have resistances above several hundred MegOhms.

**Resistivity** – A property of a bulk material of resistance through its entire area, cross section, or unit length. Usually used in reference to the physical earth as a non-homogeneous material having various different soil resistivities. Imagine a cube of soil one meter on a side. The resistance from one face plated with an ideal conductor to the opposite face so plated will be the soil resistivity in Ohm-meters. The unit of measure may also be expressed in Ohm-centimeters. The values for several substances are as follows: copper, 1.7, aluminum, 2.6, tungsten, 5.5, iron, 9.7 liquid mercury, 96, and carbon (graphite), 1400 (micro-Ohm-centimeters).

**Root Mean Square (rms)** – A mathematical conversion used to equate AC and DC currents and voltages on similar terms. For both AC and DC circuits, the power to a resistive load is its voltage drop times its current. For a DC power supply of one Volt feeding a one-Ohm resistor (drawing one Amp of current), the power dissipated would be one Watt. This would generate a certain amount of heat per hour of the power being supplied. If instead, a voltage of one Volt AC, rms (drawing a current of one Amp AC, rms) were supplied, the amount of heat derived over the same period would be the exact same value as in the DC case. One can convert any single frequency sinusoidal peak voltage or current to rms by dividing the peak value by 1.414 (same as multiplying by 0.707). The assumption necessary to use the mathematical rms conversion process is that the AC waveform is periodic, non-distorted and steady state.

**Saturable Reactor** – An electrical component used in certain AC systems to act as a voltage or current limiting device. It is physically constructed as a large number of turns of wire wrapped about a core of specially selected magnetic material with an additional control winding and other electrical components. It is used in a circuit as a serial element in line between a power source and a load, usually on the neutral side of the circuit. It functions as follows. It has a specific current rating that is like a switch point for its impedance. When current flows through the device up to its rating point, it has a very high impedance, like an open switch. When the current flowing through the device exceeds its rating, the impedance becomes small and therefore acts like a closed switch. This switching ability is not fast or dramatic and the frequency response is very low. These devices are sometimes used by certain utilities to isolate neutrals on dairy farms.

**Scalar Mathematics** – The type of mathematics used in most every day calculations concerning magnitudes. Most systems are both linear and scalar. Most DC circuits and some AC circuits are analyzed using scalar mathematics. The opposite is vector mathematics (qv).

**Secondary Electrical System** – This term refers to that part of the electrical system on the customer's side of the meter or transformer.

**Secondary Neutral to Reference Voltage ( $V_{snref}$ )** – A measurement made during a stray voltage investigation of the voltage between the main service entrance panel's neutral (which is grounded to earth at this point) and a remote reference rod. This is the main source voltage for on-farm contributions to cow contact voltage. (See K-factor).

**Secondary Neutral Voltage Drop Test (SNVD test)** – A test that is part of a Phase II SV testing protocol that looks at each farm electrical service to determine its possible contribution to cow contact voltage. For this test, one service at a time is energized and only one proxy load is powered. This load is usually a hair dryer or paint peeler having a uniform current draw at 120 V rms AC in excess of 10 Amps. Measurements are made of the physical length of the neutral from the main distribution panel to the sub-panel or load point being tested. The exact type of wire used for that neutral is noted so that its resistance per hundred feet can be ascertained. A calculation is made of the product of the distance of the neutral (in hundreds of feet) and the resistance per hundred feet resulting in the total resistance of the neutral conductor. A measurement is made of the proxy load current and, using Ohm's Law, a calculation is made of the expected voltage drop on the neutral wire at full load. The voltage drop from the source point to the load point is then measured and compared to the calculated value. If they differ significantly, this may indicate some unexpected resistance in the neutral circuit. The contribution to the cow contact voltage of this source is also measured and if it is significant, the condition is noted for possible mitigation.

**Series Circuit** – An electrical circuit in which all elements are connected in series or tip-to-tail fashion. In this type of circuit, all elements share a common current while each element has its own individual voltage drop. An example is a series string of Christmas tree lights where, when one burns out, the whole string is dark because the one common current is interrupted.

**Series Resistors** – An equivalent single resistance can be calculated for a series string of resistors by simply summing all the resistances ( $R_{total} = R_1 + R_2 + R_3 + \dots + R_n$ ).

**Shunt Resistance** – A physical resistor component used to simulate a cow during the measurement of cow contact voltage. Usually set by PSCW rules at 500 Ohms, which is a conservative value that represents the average cow (muzzle to rear hooves) and many of the contact and other source resistances in the cow contact area. Using Ohm's Law, a cow contact current can be calculated from the known value of this shunt resistance and the measured voltage across the resistance.

**Signal** – The desired component of a measurement as opposed to the undesired components of noise and interference (qqv). Unwanted noise and interferences may mask or distort signals.

**Signal-to-Noise Ratio (SNR)** – A term used in data acquisition that refers to the magnitude of the signal in proportion to the magnitude of any noise or interference that may be present. It is desirable to have this ratio as large as can be economically achieved. If the noise or interference part of a received input is not attenuated before the received input is amplified, the noise and interference will be amplified as well as the signal.

**Signature Test** – A test that is part of the PSCW Phase II SV testing protocol. In this test, all loads are de-energized on the farm during the period of testing. Then, one load is energized at a time and run for 10 to 15 seconds during which a DAS recording of the four main SV electrical parameters (qv) is made. The exact time of day of the energizing and subsequent de-energizing of the load is noted so that the electrical characteristics of the load, as recorded on the DAS, can be analyzed at a later time. Loads whose operation contributes significant levels to the cow contact voltage area are investigated for possible mitigation.

**Significant digit** – A digit that contributes to the accuracy or precision of a number. When a measurement is recorded, the more digits that are presented, the more precise the number is considered to be. For example, if a parameter being measured is exactly 0.123 V. then the true range of the reading could be anywhere between 0.1225 V. and 0.1234 V., assuming the instrument rounds the value according to the rule. If it truncates, the value could be between 0.1230 V. and 0.1239 V. In either case the 0.123 value has three non-zero significant digits. If it is written 0.12300, the implication is that the value is much more precise with a range of 0.122995 to 0.123004 using rounding or 0.123000 to 0.123009 using truncation. In this latter case, the trailing two zeros become significant digits for a total of five. The leading zero is merely a placeholder for clarity as would be the leading zeros in the number 0.00123, which still has only three significant digits. Just because a meter has many digits to display a measurement, it does not mean the digits to the right represent an exact value. The accuracy of the meter must be known in order to interpret which of the digits displayed are significant and which are questionable.

**Sinusoidal Wave** – A term used to describe the waveform of an ideal AC electrical power signal. Its shape is described by the mathematical (trigonometric) sine function. This waveform has the following characteristics. It starts at a zero level and increases in value with respect to time very quickly. At 45 degrees of the 360 degrees that constitute one cycle, it reaches 70.7 percent of its maximum amplitude. It slows the rate at which it increases until at 90 degrees, it reaches its maximum positive value. It then decreases, slowly at first and then at an ever-increasing rate, until at 135 degrees it is down to the 70.7 percent of maximum level. At 180 degrees, it returns to zero. In a mirror image to the preceding, at 270 degrees it reaches its maximum negative value and at 360 degrees it returns to zero to start another cycle. In real life, a voltage or current never follows the ideal sine wave shape exactly because of induced noises, interferences, and the non-ideal properties of the physical components of an electrical system.

**Single Phase System** – A reference to a system of primary power wiring utilizing a phase conductor and a neutral conductor to deliver electrical energy to a load. In secondary wiring, a grounding conductor accompanies the phase and neutral conductors to form a three-wire system (qv).

**Source Resistance** – A term used to refer to all the various physical resistances that exist between a source voltage and a cow contact area. It cannot be measured directly by an Ohmmeter (qv), but can be calculated by measuring the voltages at a cow contact both with and without a shunt resistance (qv) in place. The formula is as follows: subtract the voltage measured with a shunt resistance from the voltage measured without the shunt resistance. Divide that difference by the voltage measured with the shunt resistance. Multiply that result by the value of the shunt resistance and the answer is the value of the source resistance in Ohms. ( $R_s = (R_{w/o} - R_w) / R_w * R_{shunt}$ ). The PSCW would like, as a guideline, all source resistances calculated in a cow contact area to be less than 500 Ohms. This is on rare occasions not possible.

**Static Discharge** – A term referring to the flow of electrical energy from a temporary voltage source that accumulates on an insulated surface. Lightning is referred to as a form of static discharge. A more familiar example is the mild electric shock one receives when walking across a rug indoors during a dry winter day and touching a doorknob. The voltage accumulated before discharge may be many thousands of Volts, but the current during the extremely short time of the discharge is very small such that the incident is one of annoyance and not of any danger of electrocution from such a high voltage.

**Static Wire** – A metallic wire, usually steel, that is mounted atop all transmission towers to afford a measure of lightning protection. These lines are grounded at each tower. They may have a measurable level of induced voltage and current from their proximity to the high voltage/ high current phase wires of the transmission system. This arrangement is a form of a ground loop (qv).

**Steady-State** - Steady-state is defined by the Institute of Electrical and Electronics Engineers (IEEE) as the value of a current or voltage after an amount of time where all transients have decayed to a negligible value.

**Step Potential** – A voltage or potential difference measured by driving two metallic rods into the earth about five feet apart (this equals the normal stride length for a mature cow.) A shunt resistor is used with a DMM to measure a cow contact voltage that a cow walking in the same spot would be exposed to. These are generally very small levels (on the order of a few to some tens of milliVolts). Levels of step potential can be of concern when certain conditions are present. Two such conditions, for example, may be the elevated neutral to earth voltages associated with abrupt transition zones between an equipotential plane and any other area outside of the plane, and the earth's surface in close proximity to an underground electrical cable phase-to-ground fault.

**Stray Voltage (SV)** – A term with a specific definition from the PSCW. It is defined as a natural phenomenon that can be found at low levels between two contact points in any animal confinement area where electricity is grounded. Electrical systems - including farm systems and utility distribution systems- must be grounded to the earth by code to ensure continuous safety and reliability. Inevitably, some current flows through the earth at each point where the electrical system is grounded and a small voltage develops. This voltage is called neutral-to-earth voltage (NEV). When a portion of this NEV is measured between two objects that may be simultaneously contacted by an animal, it is frequently called stray voltage. Stray voltage is not electrocution and is not DC, ground currents, EMFs or earth currents. It only refers to farm animals that are confined in areas of electrical use and not to humans.

**Substation** – An area of electrical equipment within a utility power system that allows for the interface (qv) between a transmission system and either a sub transmission system or a distribution system (qqv). It may contain a combination of transformers, switching gear, busses, circuit breakers, metering devices, and other system protective gear to accomplish this task. Substations are one of the current return nodes for the three-phase distribution circuit. The three-phase distribution system may have other balance nodes where the return currents sum to zero along its length.

**Sub-Transmission Voltage Level** – Levels of electrical system voltage in the range of 30,000 to 60,000 Volts, AC, rms, phase-to-phase.

**Superposition Theorem** – A mathematical theory used to analyze linear electrical systems. In this system, a final composite value for a parameter is calculated by summing the individual contributions for that parameter of as many contributors as are present in the circuit as if they were acting separately. Certain rules are followed to derive each contribution with magnitude and sign. As such, various electrical sources can both add and subtract to produce the final net value. This is especially important to realize as AC systems involve vector (qv) quantities.

**Tap Pole** – The pole on an electrical distribution system that feeds power to an individual or group of customers. In some instances, the tap pole is where a feeder branches off that extends several spans to a rural customer's transformer pole. In other instances, it may be a pole along a distribution system circuit where a transformer is placed that feeds power to one or more customers in parallel.

**Three Phase System** – A power delivery system that uses three energized conductors with or without a neutral conductor. A wye system (qv) has a neutral conductor and a delta system (qv) has no neutral conductor. The individual phases have their cycles start at a mutual 120 electrical degree separation. One of the advantages of using three-phase loads is that they are inherently balanced and do not generate neutral current. Only various single-phase loads wired to individual phases of the three-phase system generate neutral current because they do not all draw the same amount of current at the same time.

**Three-wire System** – The original style of single-phase wiring system used in farm wiring. In this system, there are two energized conductors and a grounded neutral conductor. In every panel and sub-panel, any grounding conductor present is bonded to the neutral such that it functions merely as a parallel neutral

conductor. The NEC code has required a four-wire system (qv) (i.e. with separated neutral and grounding conductors) in agricultural facilities for many years, but true implementation to code is rarely achieved.

**Tolerance** – The number that is used to describe a range of values that a measurement of a parameter may be expected to be in. It is usually offered as a plus and minus range that is equally spaced about the ideal number. For example, a 510-Ohm resistor that has a  $\pm 5\%$  tolerance will have an exact value that is expected to be somewhere between 484.5 Ohms and 535.5 Ohms. All measurements have some accuracy limitations due to the fact that real-world components that have various tolerances are used in the construction of the instruments used to make those measurements. These components change their values slightly with temperature, moisture, and other physical conditions, so that when a measurement is made, these various conditions dictate what the accuracy of the measured value will be. When the physical conditions change, the measurement may not be as accurately repeated. This is why most measurements need only record two or three significant digits (qv) and not any more since they are not as reliable at representing the true exact value within the known or expected tolerance of the measurement system.

**Total Harmonic Distortion (THD)** – A number, expressed as a percentage, used to document the total amplitude value of all harmonics present in a waveform as a fraction of the nominal amplitude of the fundamental frequency. The THD is calculated as the sum of all individual harmonics greater than the fundamental. For example, if a voltage measurement has 1.2% 3<sup>rd</sup> harmonic, 0.5% 5th harmonic and 0.4% 7<sup>th</sup> harmonic, the THD would be 2.1%.

**Transformer (xfmr)** – An electrical component, used in AC systems, that transforms voltage and current levels through magnetic coupling and induction (qv). A transformer is physically constructed by wrapping a number of turns of a primary winding and a secondary winding around a core of specific magnetic material. The primary winding and the secondary winding are usually not conductively connected within the transformer. The ratio of the number of turns for the primary to the secondary determines the ratio of voltage and current increase or decrease. For example, if a transformer's primary is designed for 7,200 volts and its secondary is designed for 240 volts, the turns (and voltage ratio) is 30 to one. That ratio also describes the increase in current on the secondary side. If the primary current is 6.94 Amps, then the secondary current will be 208.2 Amps. Note that the Volt-Amp products of the primary and the secondary sides are equal, i.e.  $7,200 * 6.94 = 240 * 208.2 = \text{about } 50 \text{ kVA}$ .

**Transient** – A term that describes an event or disturbance on an electrical system that occurs randomly or occasionally and may last a very short time in comparison to the time of one cycle of the fundamental frequency. The longest lasting transients are motor starting transients that may significantly increase currents or decrease voltages for up to as much as 30 or more electrical cycles. Much shorter transients are sometimes found on power system wires that are induced or radiated from trainers, crowd gates, and fences and nearby lightning strikes. These are characterized by extremely short durations and may have voltage levels that are fairly high. Because of the time versus voltage nature of these transient signals, they usually do not contain much energy. They therefore have to be at very significant levels to be felt by farm animals. Random transients of high voltage and short duration may come from nearby arcing that occurs in secondary breaker operations and motor start relays, or momentary primary system switching or faults. They are usually single or grouped events that are not repeated and are usually of little consequence. Because an electrical system is like a distributed network of inductances and capacitances (qqv), fast rise and fall time transients will have the rise and fall times slowed and attenuated significantly with increasing distance traveled on the electrical system conductors. This effect is more pronounced on primary systems than on secondary systems.

**Transmission System** – A part of the primary electrical system that receives energy from the generation system (qv) and delivers it to the distribution system (qv), sometimes over significant distances. Higher voltages are desired so that the current that must be carried on the non-zero resistance conductors is relatively low for a fixed amount of delivered power. Losses are calculated using Ohm's Law, meaning that the lower

the current in the fixed resistance conductors, the less voltage drop will occur and therefore the less power will be expended delivering the electrical energy to the load. To afford a measure of lightning protection, a grounded static wire (qv) is mounted at the highest point above all transmission lines. Many Wisconsin transmission systems have a wye-connected transformer with the neutral center tap at the sending end grounded for reference. Because the transmission system is always a balanced three-phase system, little or no neutral/ground current is created. Because of the high voltages and currents used in transmission systems, the area underneath the system usually is an area that can have significant levels of electric and magnetic fields (qqv).

**Transmission Voltage Level** - The voltage levels of transmission systems are higher than 60,000 and may range up to as high as 345,000 Volts AC, rms, phase-to-phase in Wisconsin.

**Variable Threshold Neutral Isolator Device** – A recently designed variation of the neutral isolator device (qv) that re-closes the neutral connection at different (higher) voltage levels depending on the (shorter) duration of transient voltages across the device. For steady state voltages of about 26 volts on either neutral, the switch will close and connect the primary and secondary neutrals for as long as the voltage remains above that level. The shorter duration the transient is, the higher the voltage level needed to close the switch.

**Vector Mathematics** - The type of mathematics used to analyze AC voltage, current, and impedance circuits. In mathematics, vectors are representations of physical quantities that have both a magnitude and a direction. Electrical vector quantities can be mapped on a plane surface with X and Y grid coordinates. Zero degrees is in the direction of the positive X axis. The best analogy is to compare them to positions and distances on a map. Consider that the distance from Madison to Green Bay is roughly 140 miles. The direction that Green Bay is from Madison is roughly northeast or 45 degrees from north. It is important to specify a direction so as not to travel 140 miles in any random direction (ending in Chicago, for instance, if the direction happened to be southeast – 135 degrees from north). All AC voltages, currents, and impedances are vector quantities. Adding these quantities is like adding distance and direction on a map in a tip-to-tail fashion. Journeying from Madison to Green Bay, 140 miles northeast, and then 78 miles west (to Stevens Point) and then 68 miles south is the same as journeying 36 miles due north of Madison (end point, Portage), but is a much longer route! The same example for voltages would read 140 V. at an angle of 45 degrees plus 78 V. at an angle of 180 degrees plus 68 V. at an angle of 270 (or minus 90) degrees. The result would be 36 V. at an angle of 90 degrees. If one just added the scalar values of 140 V., 78 V. and 68 V. the sum would be 286 V. – clearly different from 36 V. Because voltages add in a vector fashion, neutral to earth and cow contact voltages can be the sum *and/or difference* of the various source voltages that contribute to their value.

**Voltage (V)** – The electrical quantity that describes the push or potential that electrical energy has to flow in a circuit. It is one of three parameters used in Ohm's Law (qv). It is always measured as a difference between a higher potential and a lower potential, even if the lower potential is zero (earth reference). Voltage can appear as a source that exists in either an open circuit (producing no current) or closed circuit (producing current) or as a closed loop voltage drop (qv) that is the Ohm's Law reaction of a current to a resistance. Voltage is never measured 'on' something, but is always measured as *between* two points.

**Voltage Drop** – Whenever a current passes through a resistance or impedance in a closed loop circuit, a voltage drop (or IR drop (qv), according to Ohm's Law) is produced across that resistance or impedance.

**Voltmeter** – An electrical instrument used to measure voltage either as a source or as a voltage drop. The instrument may measure AC or DC voltage depending on its design. For AC voltage measurements, a specific range of frequencies is usually specified within which an accurate measurement may be made. It is important to know the specifications of the AC voltmeter as it presents its reading as to whether the voltage is calculated rms, true rms, peak, peak-to-peak or average. The input impedance (qv) of the voltmeter is an important property of this device.

**Watt (W)** – An electrical unit describing power expended. In formulas for simple DC circuits, power is equal to voltage times current or voltage squared over resistance or current squared times resistance. For an electrical system having a one-Volt source feeding a load (of one Ohm) drawing one Amp of current, one Watt of power is being supplied. In AC circuits, because of the inclusion of frequency and multi-phase circuits, AC power formulas can be more complex. Power is an instantaneous quantity, as opposed to energy, which is defined as power utilized over a specific time. Electrical energy is measured in Watt-hours or, more commonly, in kiloWatt-hours.

**Watt-Hour meter** – An electrical device used to measure energy consumption. For example, if a 750-Watt (roughly 1 horsepower) load is connected to a power system for 12 hours, it will use 9,000 Watt-hours (9 kWhr) of energy.

**Wattmeter** – An electrical device used to measure instantaneous power. It usually measures both voltage and current simultaneously and displays their product. For AC wattmeters, the product of the rms voltage and the rms current times the cosine of the phase angle between the two is the real power while the product of the rms voltage and the rms current times the sine of the phase angle between the two is the reactive power which is expressed in VAR's (VoltAmps reactive). The product of the rms voltage and the rms current is the apparent power expressed in VA's (VoltAmps). Real power is able to perform work, while reactive power is not able to perform real work.

**Waveform** – A term used to describe the shape (amplitude versus time) of an AC electrical quantity such as voltage or current. AC electrical systems are generally characterized by ideal sinusoidal waveforms. Real world electrical systems never have ideal sinusoids. They are distorted both in amplitude and time by a great number of factors.

**Wavelength** – The distance in space occupied by one complete cycle of an AC waveform. This quantity is related to the inverse of frequency (qv). They are related by the formula, wavelength equals the speed of light divided by the frequency. Using c, the speed of light, as 3 times 10 to the 8<sup>th</sup> meters per second, a 27 MegaHertz (the citizen's band radio frequency) wave is 11 meters (about 36 feet) long. One quarter wave (qv) of this value, the ideal antenna (qv) length, would be 2.75 meters long – just over 9 feet.

**Wye (Y) Configuration** – A term used to describe a three-phase electrical system with or without a neutral conductor. When a neutral conductor is present, it will carry any imbalance current from the three phase wires. The value of the imbalance current is calculated using vector mathematics for the currents. For example, a system having a phase A current of 12 Amps, a phase B current of 10 Amps and a phase C current of 18 Amps will have a neutral current of just over 7.2 Amps. The phase angle will be minus 106 degrees (slightly out-of-phase with phase C).

The End